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TOWARD THE ENGINEERING FEASIBILITY OF THE CENTRIFUGAL NUCLEAR THERMAL ROCKET

Abstract

The Centrifugal Nuclear Thermal Rocket (CNTR) is a Nuclear Thermal Propulsion (NTP) concept designed to heat propellant directly by the reactor fuel. Rather than using traditional solid fuel elements, the CNTR uses liquid fuel with the liquid contained in rotating cylinders. Successful realization of the CNTR would have a high specific impulse (1800 s) at high thrust, which may enable viable near-term human Mars exploration by reducing round-trip times to 420 days. The CNTR could also use storable propellants such as ammonia, methane, or hydrazine at an Isp of 900 s, enabling long-term in-space storage of a dormant system. While the basic theoretical approach underlying the CNTR is well understood, significant engineering challenges must be addressed to establish the technical viability of the CNTR. These engineering challenges include:

- Heat transfer between metallic liquid uranium and the propellant; - Demonstration of a porous cylinder wall which will contain the liquid uranium yet allow propellant to flow into the rotating cylinder; - Accommodation of startup and shutdown transients; - Control the loss rate of the liquid uranium in the rocket exhaust stream; - Neutronic design of the reactor core to assure stable operation during startup, steady-state, and shutdown. - Reliable techniques for rotating the cylinders at several thousand RPM and which will safely accommodate the failure of individual cylinders.

This list of engineering challenges requiring resolution to achieve viability for the CNTP is long and the challenges are unfortunately interdependent, making it difficult to decide where to begin. The basic approach is to work the challenges from the inside out, beginning with the heat transfer inside the reactor between the liquid fuel and the gaseous propellant, and then proceed to the other challenges.

Research is presently underway to determine resolutions for these engineering challenges. In particular, research has begun on the analytical modeling and simulation of the two-phase heat transfer between the liquid metallic uranium fuel and the gaseous propellant. This investigation focuses initially on a static laboratory model where suitable liquid and gas model fluids can be evaluated for subsequent studies. This is essentially a heat exchanger with a direct-contact (bubbly flow) section followed by a free-surface

gas/liquid convection section. The size and stability of the bubble trains formed for the liquid/gas pairing can be observed and overall efficiency of the heat exchanger can be evaluated and modelled.

Subsequent research will progressively address the remaining CNTR engineering challenges.